990-123

4.5 PSP Cover Sheet (Attach to the front of each proposal)

Proposal Title: Dissolved Organic Carbon Release from Delta Wetlands Part 1.
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Amount of funding requested: $ 1,392,669.00 for 3 years

Indicate the Topic for which you are applying (check only one box).

- ☐ Fish Passage/Fish Screens
- ☐ Habitat Restoration
- ☐ Local Watershed Stewardship
- ☒ Water Quality
- ☐ Introduced Species
- ☐ Fish Management/Hatchery
- ☐ Environmental Education

Does the proposal address a specified Focused Action? X yes ____ no

What county or counties is the project located in? Yolo, Solano, Contra Costa, San Joaquin, Sacramento

Indicate the geographic area of your proposal (check only one box):

- ☐ Sacramento River Mainstem
- ☐ Sacramento Trib: ____
- ☐ San Joaquin River Mainstem
- ☐ San Joaquin Trib: ____
- ☒ Delta: ____
- ☐ East Side Trib: ____
- ☐ Suisun Marsh and Bay
- ☐ North Bay/South Bay: ____
- ☐ Landscape (entire Bay-Delta watershed)
- ☐ Other: ____

Indicate the primary species which the proposal addresses (check all that apply):

- ☐ San Joaquin and East-side Delta tributaries fall-run chinook salmon
- ☐ Winter-run chinook salmon
- ☐ Late-fall run chinook salmon
- ☐ Delta smelt
- ☐ Splittail
- ☐ Green sturgeon
- ☐ Migratory birds
- ☒ Other: Potentially all eco-system organisms
- ☐ Spring-run chinook salmon
- ☐ Fall-run chinook salmon
- ☐ Longfin smelt
- ☐ Steelhead trout
- ☐ Striped bass
- ☐ All chinook species
- ☐ All anadromous salmonids

Specify the ERP strategic objective and target (s) that the project addresses. Include page numbers from January 1999 version of ERP Volume I and II:
ERPP v.1, p18, EIR/EIS Exec. Sum.,p 5, Rev. Wat. Qual. Proj. Plan, p. 15, ERPP, v. 2 p 79, ERPP v. 2, p 83

Indicate the type of applicant (check only one box):

- ☐ State agency
- ☐ Public/Non-profit joint venture
- ☐ Local government/district
- ☐ University
- ☒ Federal agency
- ☐ Non-profit
- ☐ Private party
- ☐ Other: ____________________

Indicate the type of project (check only one box):

- ☐ Planning
- ☐ Monitoring
- ☒ Research
- ☐ Implementation
- ☐ Education

By signing below, the applicant declares the following:

1.) The truthfulness of all representations in their proposal;

2.) The individual signing the form is entitled to submit the application on behalf of the applicant (if the applicant is an entity or organization); and

3.) The person submitting the application has read and understood the conflict of interest and confidentiality discussion in the PSP (Section 2.4) and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent as provided in the Section.

Dr. Brian A. Bergamaschi

Printed name of applicant

Signature of applicant

Executive Summary

BACKGROUND:

Rivers, wetlands, and agricultural operations supply organic material to the Sacramento-San Joaquin Delta and San Francisco Estuary – essential nutritive material supporting the aquatic foodweb. Unfortunately, the presence of high concentrations of organic material cause public health concerns. Delta waters are currently used by over 22 million people for drinking water. When treated with disinfectants such as chlorine or ozone, dissolved organic carbon (DOC) and naturally occurring bromide in water can form carcinogenic disinfection byproducts (DBPs). The concentration of DBPs in drinking water is stringently regulated by US EPA.

CALFED ecosystem restoration activities seek to restore wetland habitat and provide sources of organic material beneficial to the Bay and Delta foodweb. While as many as 100,000 acres may be converted to wetland habitat in the Delta, it is not known if these wetlands will alter the concentrations of organic material prone to forming DBPs. The primary goal of this research is to provide the scientific information that will allow CALFED to maximize the ecological benefits of new wetland habitat while minimizing sources of organic material that would adversely impact Delta drinking water quality. An example of how this might be accomplished would be to restore only specific types of wetlands – those exporting small quantities of deleterious organic carbon – on flow paths affecting drinking water intakes.

At present, there is little information available regarding the amount or quality of organic material released from different types of wetlands (or even agricultural sources) and its effect on either the Delta foodweb or drinking water treatment. Consequently, the following 5 questions, listed in order of importance, have been identified by CALFED as the highest priority information needs for assessing the potential effect of ecosystem restorations on dissolved and total organic carbon (DOC, TOC) levels in the Delta:

"1. *How much and what forms of TOC do wetlands generate?"*

"2. *To what extent is TOC released from wetlands altered and consumed in Delta waters?"*

"3. *By comparison, how much and what forms of TOC are released from agricultural activities?"*

"4. *What wetland management strategies may be used to limit introduction of TOC into Delta waters?"*

"5. *How will the impacts of restored wetlands change in the future as they mature?"*

APPROACH:

To answer each of these questions, independent information is needed about both the **form** of TOC and the **amount** of TOC released from various wetlands and agricultural operations. TOC is made up of particulate (POC) and dissolved organic carbon (DOC). The chemical composition – the form of TOC – varies widely, and different forms of TOC react to produce different amounts and types of DBPs. The form of the TOC also affects the potential foodweb benefits because different forms are utilized to different degrees. The amount of TOC released by different land uses (such as different wetlands) also varies widely.

This proposal focuses on issues related to the **form** of TOC, examining a variety of representative wetlands, rivers, and agricultural sites. We chose to submit a companion proposal that quantifies TOC export from a single wetland and agricultural site since determining the **amount** of TOC exported is an expensive and difficult task that requires using a different technical approach. Together with results from a previously funded CALFED study examining particulate organic carbon (POC; J. Cloern), these two proposals will provide a quantitative basis for estimating the relative contributions of TOC from different wetlands into the Delta, and permit an accurate comparison to current agricultural activities. This proposal focuses on DOC because it is the dominant form of organic matter exported from wetlands to Delta Channels and is the most likely to form DBPs. When complete, these projects will integrate.with the existing CALFED study of POC and provide a comprehensive assessment of TOC in the Delta system..

The goals of this project are to: 1) characterize the concentration and quality of DOC released from different wetland types within the Delta and by agricultural activity, assessing both incorporation into Delta foodwebs and public health concerns that arise when Delta waters are used as drinking water; and 2) determine how microbial alteration affects the quality of the DOC and thus changes the concentration of the small fraction of DOC causing public health concerns.

STUDY DESIGN:

Past research on DOC in Delta waters indicates that: the source of DOC is a key factor for both ecosystem and drinking water concerns. For drinking water, it is known that only a small fraction of DOC forms DBPs; that concentrations of precursors by 10 fold depending on location within the Delta; and that DOC concentrations vary by 10-20 fold across the system. The amount of precursors in the DOC is highly dependent on the source and extent of degradation of the organic material. Similarly, the source and quality of the organic carbon is important to the microbial part of the foodweb as it determines the intrinsic lability and nutritive value. In addition, DBP precursor formation is linked to microbial use and degradation of DOC.

We propose to separately characterize the DOC from different Delta sources to understand how DOC released from wetlands is incorporated by microbes for eventual transfer to higher trophic levels (copepods, cladocera, rotifers, mysids and fish or species of special concern). Simultaneously, we will examine changes in chemical composition before and after microbial degradation, as they relate to DBP formation potential. When coupled with accurate physical modeling, these results will provide a quantitative basis for estimating the impacts of restoration efforts on organic carbon supply to the Estuary and to drinking water intakes.

This study will first survey a variety of representative wetlands over the seasons to determine the extent to which wetland-derived DOC forms DBPs, and the extent to which wetland-derived DOC forms DBPs and causes other difficulties in the treatment process. Next, it will explore bioutilization of this material and the extent to which DBP formation by DOC from different sources is altered by natural processes such as microbial degradation and photolysis. Finally, it will relate the composition and reactivity of the DOC to landscape-level features and environmental factors within the wetlands.

For a comprehensive examination of these issues, we have assembled a team of scientists who will employ an array of scientific tools. The team will be led by Brian Bergamaschi of the U.S Geological Survey. He and J. T. Hollibaugh will bear responsibility for all scientific products. The various team members bring a wealth of scientific experience in microbial degradation, photolysis, carbon release from peat soils, wetland ecology, chemical characterization of natural organic material, organic geochemistry, application of isotopic techniques to foodweb interactions, drinking water treatment, and the chemistry of DBP formation. The progress and products of the study will be monitored by an independent scientific advisory panel composed of internationally recognized experts in DOC release from wetlands, chemical characterization of DOC, aquatic foodweb interactions, drinking water water treatment, and DBP formation. The final reports will analyze and synthesize the experimental results to identify specific options to CALFED regarding the potential impacts of different restoration actions on Delta drinking water quality and DOC-supported biological production in the Delta.

Project Description

BACKGROUND:

To restore ecological health and improve water quality in the Bay-Delta system, over 100,000 acres in the Delta may be converted to wetlands. This ecosystem restoration will cause a shift in land use away from current, largely agricultural uses, to different types of wetlands. Since the organic matter produced and exported to the Delta channels by wetlands is likely to differ markedly from that discharged from agricultural lands, this shift will likely affect both Delta drinking water quality as well as the Delta foodweb that depends on DOC.

In the drinking water treatment process, disinfectants such as chlorine and ozone react with naturally occurring organic matter and bromide in the source water to produce carcinogenic by-products (DBPs). The levels of these DBPs in drinking water are regulated by the US EPA, and regulations are likely to become more restrictive in the near future (Krasner 1994). Similarly, the nutritional value of organic matter exported from the different wetland types and used by the Delta foodweb is likely to change as land uses change. To assess and optimize the benefits of wetland restoration and to manage deleterious impacts, it is necessary to characterize the DOC as it is produced in tidal wetlands, non-tidal wetlands and agricultural lands, to understand how DOC is utilized, degraded, and transformed by microbial action, to determine how these transformations affect DBP formation potential, and to examine how they benefit the Delta foodweb.

The chemical composition of the organic carbon determines both the potential for formation of DBPs as well as the nutritional value to the Delta foodweb. The total organic carbon (TOC) in water is composed of particulate (POC) and dissolved (DOC) fractions. While it is possible for POC produced in wetlands to contribute to the production of DBPs, it is most likely that natural physical and biological processes, and standard water treatment techniques will limit its role. On the other hand, wetland-produced POC is important as a food resource that supports fish recruitment. POC dynamics are being assessed by Cloern *et al.* in a CALFED Category III study. However, an unknown fraction of Delta organic matter production enters the Delta foodweb as DOC via consumption by the heterotrophic microbial community. Thus, DOC released from wetlands and agricultural activities into Delta channels is the organic carbon fraction of most importance to drinking water utilities, and it may represent an important element of the Delta foodweb.

Therefore, the goals of this project are to: 1) characterize the concentration and quality of DOC released from different wetland types within the Delta and by agricultural activity, assessing both incorporation into Delta foodwebs and public health concerns that arise when Delta waters are used as drinking water; and 2) determine how microbial alteration affects the quality of the DOC and thus changes the concentration of the small fraction of DOC causing public health concerns.

SCOPE OF WORK:

DOC exported by the different Delta wetland types and by agriculture will be characterized for its microbial Delta foodweb value, and its propensity to form DBPs. We will sample and compare waters from 10 sites, spanning representative tidal and non-tidal wetlands, rivers, and agricultural land over 24 months. We will chemically characterize the DOC of this water and determine its DBP formation potential as well as other parameters of interest to drinking water utilities. Samples will be characterized both before and after incubation with the natural microbial assemblage and photolytic degradation. The mesocosm incubation experiments will examine DOC incorporation into the foodweb and the effect of microbial community metabolism on the chemical characteristics of DOC from the different sources. Finally, the chemical and isotopic signature of DOC, bacterial biomass and DBPs will be used to trace the source of DOC in the Delta channels.

The results of this study will provide quantitative estimates of DOC from wetlands useful for evaluation of the potential contribution of different wetland types to Delta drinking source water quality and the Delta foodweb.

Conceptual approach:

The approach used in this study is most easily described using our conceptual model of DOC sources and fates in the Delta system (Fig. 1). DOC is produced by a variety of sources within the Delta, as well as imported from outside the Delta, depicted by the multiple arrows on the left side of Figure 1. Once in the Delta, DOC is modified by several interrelated natural processes, the most quantitatively important of which are likely to be photolysis and biodegradation. These processes, represented by the boxes and arrows in the center of Figure 1, supply nutritive material to the Delta foodweb via the microbial loop, and transform the organic material during transit through the Delta. Transformations include chemical alteration of organic material, *de novo* synthesis by secondary producers, as well as addition of DOC by algae and floating aquatic macrophytes in Delta channel waters. (Algal and macrophyte production are being measured as part of the POC study, shown as the blue box in the lower part of Figure 1.) Following transit through the Delta, some water is removed for use as drinking water, depicted by the upper arrow on the right side of Figure 1. This water may be subject to a variety of treatments prior to distribution into the potable water supply, and some types of organic carbon compounds are problematic in this treatment process.

The questions in Figure 1 indicate areas where significant gaps in our knowledge about sources or processes exist, and represent the focus of our analytical efforts. Together they provide an outline of our study design, the intent of which is to provide a broad understanding of important sources and processes that affect DOC concentration, composition, and degradation in the Delta.

Study Design:

This proposed study will sample DOC from wetlands of various types, from rivers, and from agricultural runoff (see Table 1 for prospective sites). Each of these source materials will be characterized as to DOC composition, biodegradability, photolytic susceptibility, isotopic composition, DBP precursor content, and other parameters. Compositional measurements will include carbohydrate content, lignin-phenolic content, ^{13}C CPMAS-NMR functional group composition, fatty acid content, and others. These data will be compared to measurements made on samples collected by other studies (J. Cloern, POC, C. Simenstad, Breached Levee) to identify sources and establish isotopic and compositional calibrations.

DOC will also be collected from each of the sites and its rates of utilization, incorporation, and transformation determined using mesocosm studies combined with isotopic measurements. Following degradation and transformation in mesocosms, the remnant organic carbon will be characterized as to chemical composition and DBP precursor content. The extent to which DOC is transformed by biodegradation and photolysis, and the extent to which it is incorporated into Delta foodwebs will be estimated by examining changes in compositional and isotopic indices using established methods. In this way, the potential foodweb benefits as well as the potential impacts on drinking water utilities of the *remnant* material (see Fig. 1) will be determined for each of the sources. Both parameters are important as models are developed incorporating realistic flow and degradation rates of organic carbon in Delta waters. These models are important for siting and predicting the impact of wetland restorations in the Delta.

Finally, DOC samples from Delta channels will be collected and compositional and isotopic measurements will be used to compare them to sources, and source materials degraded in the mesocosm studies. Additionally, the contribution of the various sources to the DBP precursor content of Delta channel DOC will be estimated by measurement of the isotopic composition of the

Conceptual Model and Rilation to Existing Study

DOC PRODUCTION

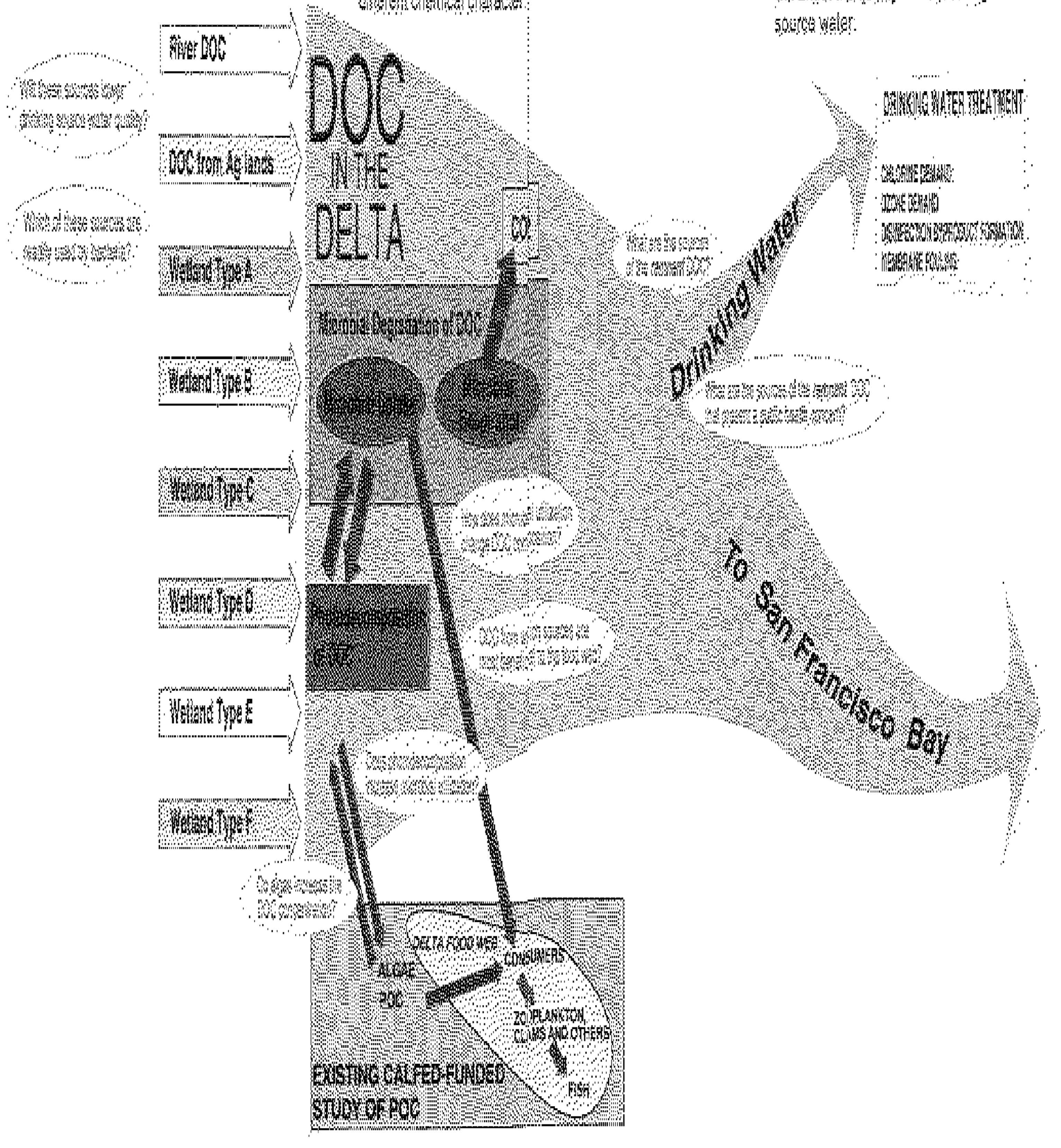
The different types of DOC from the different sources mix into Delta waters.

DOC DEGRADATIONAND UTILIZATION WITHIN THE DELTA

DOC is consumed by microbial respiration in Delta waters, leaving *remnant* DOC of different chemical character.

DRINKING WATER CONCERNS

Some Delta water is used as drinking water. The quality and amount of DOC will affect the quality of the drinking source water.



DBPs themselves. Previous studies have shown that DBPs retain the isotopic signature of the source materials. Channel sampling sites will be immediately adjacent to wetland study sites (Fig.2, Table 2).

TASKS:

There are seven independent but interrelated tasks associated with this project.

Table 1. Project tasks.

TASK	DESCRIPTION	Task lead and participants
Task 1A. Sources	Characterize the quality and concentration of organic carbon contributed to the Delta by the different land-use types. DOC composition from various wetlands and agricultural sources will be monitored over seasonal time scales and related to environmental factors such as tidal flushing, residence time, and wetland vegetation type.	Dr. Brian Bergamaschi Dr. Miranda Fram Dr. Roger Fujii Dr. Rich Losee Stuart Krasner
Task 1B. DBP formation	Determine the DBP formation of material from different sites, and compare to compositional parameters determined in Task 1A. Relate formation potential to landscape characteristics.	Dr. Rich Losee Stuart Krasner Dr. Brian Bergamaschi Dr. Miranda Fram
Task 2. Foodweb Value	Characterize the value to the Delta foodweb of DOC from the various Delta sources. This task will evaluate DOC entry into the Delta foodweb through uptake by the microbial community using incubations with the natural microbial community. The role of photolysis as it effects the nutritive value of the DOC will also be assessed by this task.	Dr. J.T. Hollibaugh Dr. Mary Ann Moran
Task 3. Changes in DOC	Characterize the chemical transformations of the DOC generated by the different Delta sources and mediated by the microbial community and photolysis. Samples for this task will be provided by activities in Task 2.	Dr. Brian Bergamaschi Dr. Roger Fujii Dr. Rich Losee Stuart Krasner Dr. Miranda Fram
Task 4. Channel DOC	Estimate the origins of DOC contributing to the pool of DBP precursors in drinking water by correlating the isotopic ratios of DBPs with that of the various DOC sources. This component will provide key data necessary to develop a synthesis of results, as well as guidelines and recommendations to CALFED about the potential impacts of restoration actions.	Dr. Miranda Fram Robert Dias Dr. Carol Kendall Dr. Brian Bergamaschi
Task 5. Synthesis report	Develop a synthesis of the results. This interpretive report will compare the quantity and quality of DOC generated by different habitat types, and to predict the general impacts of different restoration scenarios on: 1) the quantity and quality of DOC transported to municipal drinking water intakes, and 2) the Delta foodweb through uptake by the microbial community. This task will begin June 2002 and be completed December 2002.	Dr. Brian Bergamaschi Dr. J.T. Hollibaugh
Task 6. Science Advisory panel	Appoint a scientific advisory panel consisting of experts in wetland organic carbon production, DOC chemical characterization, isotopic tracers, DBP formation potential, and the Delta foodweb that will be convened to provide advice and guidance and ensure intellectual quality control. The panel will review the project work plan, and all reports.	Dr. Brian Bergamaschi
Task 7. Project management	To be performed by the USGS. Project management, including administrative support, financial reporting, report editing and preparation, and maintenance of the project web site.	Dr. Brian Bergamaschi

Tasks 1-4 will produce annual and final scientific reports. Task 5 will synthesize elements of tasks 1-4 into specific recommendations to CALFED. Task leaders will bear responsibility for report preparation. Tasks 1, 2 and 3 represent the core of this project and can not be separated. Separate knowledge of the source, chemical composition, and degradability of DOC is required to predict the effects of contemplated land-use changes. The fourth task could be separated for funding at a later time, but it would cost much more as the field component is highly integrated into tasks 1-3. Identifying the wetland sources of carbon entering the foodweb or at the drinking water intake will directly establish the relationship between sources and the points of interest. Task five, the synthesis of results, can not be separated. The scientific advisory panel, task six, can be separated or reduced, but we think that the scientific credibility provided by a panel of expert peers to review project products is important. The questions addressed here are very complex and elimination or reduction of the panel may affect the high quality of the final product.

Location and/or Geographic Boundaries of the Project:

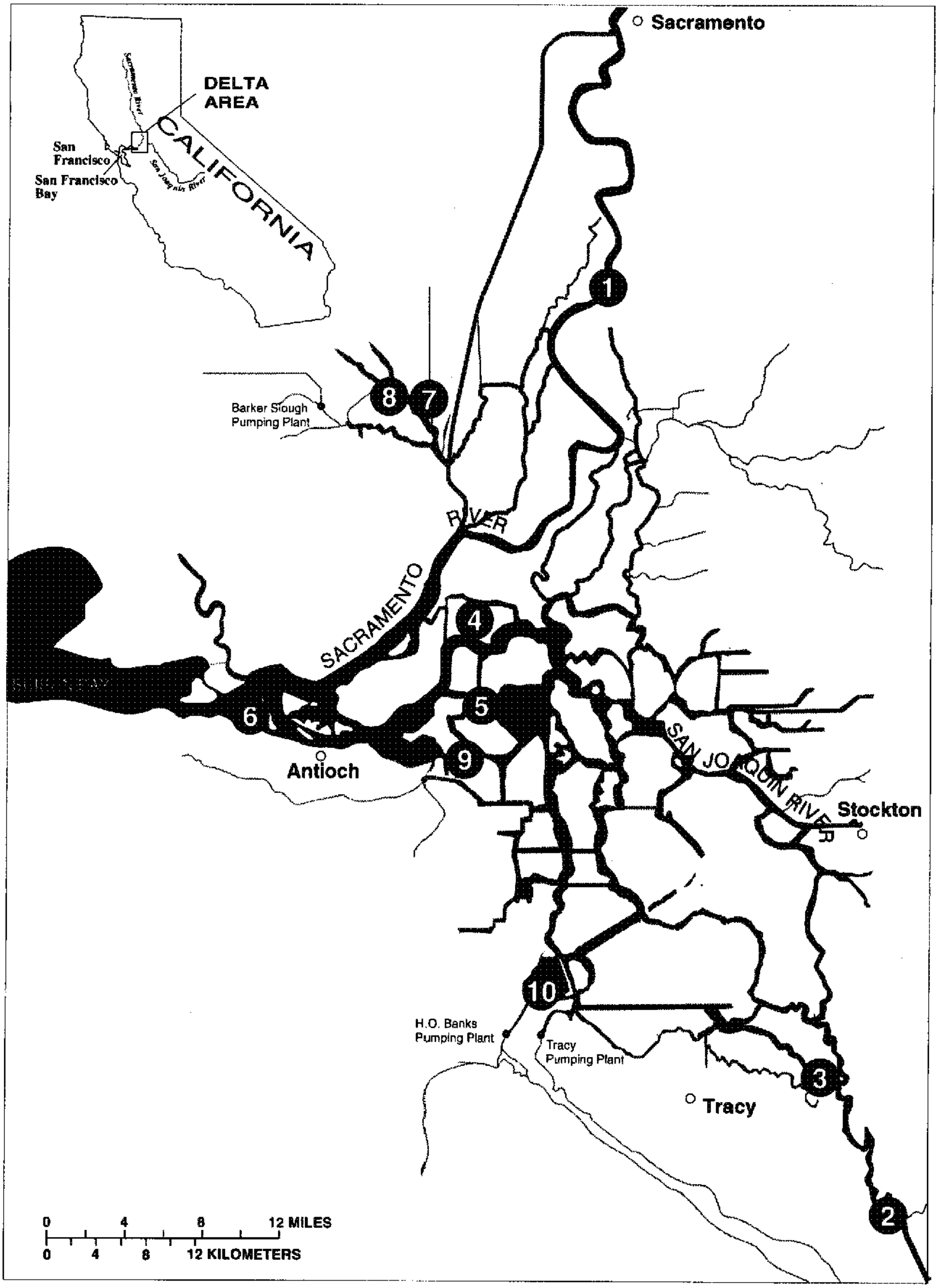
Map (Fig. 2) and Table 1 describe prospective sampling sites. @

Table 2. Description of proposed study sites.

Habitat Type	Expected Sources of DOC	Proposed Site
1. Sacramento River	multiple sources from the Sacramento River watershed	Hood
2. San Joaquin River	multiple sources from the San Joaquin River watershed	Vernalis
3. Long-retention slough	phytoplankton, and agricultural	Paradise Cut (near San Joaquin River)
4. Agricultural drain	peat soils and residual crop biomass	Twitchell Island
5. Shallow Lake (flooded island)	submerged, emergent, floating vascular plants	Little Frank's Tract
6. Tule wetland	emergent vascular plants	Brown's Island
7. Narrow tidal-river channel	riparian, agricultural, emergent plants	Shag Slough (near intersection of Cache Slough and Sacramento River)
8. Shallow lake	riparian, emergent, and floating plants	Cache Slough Mitigation area (or Little Hastings Tract)
9. Long-retention tidal slough	phytoplankton and vascular plants	Dutch Slough (between Franks Tract and Big Break
10. Drinking water intake	integration of Delta processes	Clifton Court Forebay

Figure 2

Map of proposed study area



Ecological/ Biological Benefits

This project provides substantial ecological benefit by determining the use of DOC from different sources by the Delta foodweb and provides information necessary for predicting changes to the foodweb that may arise from CALFED wetland restorations. Bacteria consume some of this DOC and, thus, microbial growth at the expense of Delta DOC has the potential to affect the quality of drinking water sources in the Delta. However, DOC in Delta waters used as drinking water can pose serious public health concerns through the formation of disinfection byproducts, or in some cases by preventing adequate disinfection. Hence, the ecological and biological objectives of this project are to 1) Determine the differences between wetland types and an agricultural field in the concentration and quality of DOC they produce; 2) Assess the quality of DOC produced by different wetland types and an agricultural field with respect to public health concerns that arise when Delta waters are used as drinking water; 3) Determine to what extent microbial processing alters the quality of DOC produced by different wetland types and an agricultural field, thus altering the concentration of the small fraction of DOC causing public health concerns; 4) Determine the differences between wetland types in the bioavailability of the DOC they produce and assimilation into the microbial foodweb; and 5) Estimate the amount of wetland- and agriculturally-derived DOC occurring in Delta waters, and thus the potential of DOC from these sources to reach export locations.

The principal sources of organic carbon in Delta waters are: 1) material carried into the Delta by river inflow (this includes terrestrial plant debris and soil particles as well as dissolved material leached from soil and decaying vegetation), 2) higher plant biomass, detritus and exudates released by wetland and riparian vegetation, 3) organic material produced in Delta channels by the growth of phytoplankton or benthic algae; and 4) organic material discharged from agricultural operations on Delta Islands. There are potentially significant quantitative and qualitative differences in the organic material supplied from each of these sources. For example, terrestrial material is abundant during winter floods but much of it washes through the Delta without benefit to the Delta foodweb because high current velocities prevent settling of POC; while low water residence times and cold temperatures characteristic of winter high flow events inhibit microbial consumption of DOC. Also, river-borne material is typically highly degraded and thus is not a good food source.

Phytoplankton production is typically high during summer when light and water temperatures are elevated, residence times are long and grazers are abundant. Phytoplankton-derived DOC typically represents material of high nutritive value. Material produced by wetlands and riparian vegetation is thought to be of intermediate ecological value between and little or no work has been done to characterize the trophic role of organic material in agricultural drainage water. Thus, restoration of tidal and non-tidal wetlands in the Delta and replacement of agricultural lands with wetlands is likely to change the concentration and quality of organic matter in Delta channel waters.

Organic matter, whether dissolved or particulate, provides the fuel for Delta foodwebs. Both classes of organic matter are composed of a wide range of compounds with different nutritional values, hence the overall nutritional value of organic matter from different sources varies depending on the composition of this mixture. As its name implies, particulate organic matter (or particulate organic carbon, POC) is present in the form of particles that can be consumed directly by invertebrate filter feeders which in turn provide food for larval and juvenile fish. POC can also be removed from drinking water during treatment either by filtration or settling. CALFED is currently funding a study of the sources of Delta POC and its role in Delta foodwebs that will determine the nutritional value of POC produced by different wetlands and will help us predict the impact of restoration efforts on POC supply. However, the POC study will not address the sources, fate, nutritional value or public health concerns raised by of the much larger pool of DOC found in Delta water

DOC cannot be consumed directly by filter-feeders, but rather is processed by a subsidiary foodchain initiated by heterotrophic bacteria that selectively use some of the dissolved organic matter as a carbon and energy source. Bacterial growth utilizing DOC generates fine particulate material (the bacteria themselves) that is available to the Delta foodweb via a sequence of trophic transfers, known as the "microbial loop." DOC concentrations in the Delta often exceed POC concentrations by factors of 2-10 and recent findings (Werner and Hollibaugh 1993; Hollibaugh and Wong 1996) suggest that the microbial loop may be quantitatively important to the San Francisco Bay Estuary entrapment zone foodweb. The role of microbial loop processes in the Delta foodweb is not known but is expected to be large because of the higher concentrations of DOC found there relative to the entrapment zone.

In addition to their role in transferring DOC to higher trophic levels, bacteria also play a role in determining the qualitative characteristics and chemical composition of DOC by selectively removing some compounds while leaving others behind. They are aided in this process by sunlight, which activates some compounds, making them susceptible to microbial degradation (Miller and Moran 1997; Moran and Zepp 1997). As a result of the heterogeneity of DOC sources and its subsequent processing in the Delta, the chemical composition of DOC is quite variable between Delta locations. An example is the difference in the amount of aliphatic carbon found in DOC isolated from different sites (Bergamaschi et al. 1999). Aliphatic compounds, e.g. fats and lipids, are among the most biodegradable of organic compounds. However, the fraction of aliphatic carbon in DOC isolated from Clifton Court (see Fig. 2) was 23% higher than the amount found in San Joaquin River water. These chemical differences also affect the formation of DBPs. A greater than 10 fold difference in DBP formation has been observed in Delta waters with equivalent DOC concentrations, attributable to differences in chemical composition (Fujii et al., 1998). The stable isotope signatures of DBPs formed in water taken from different Delta locations are also different (Fram, et al. 1998; Bergamaschi et al. 1999), indicating that the carbon precursors to DBP are different at different locations in the Delta.

Selective removal of some compounds during microbial processing of DOC is likely to affect the propensity of the remaining DOC to form DBPs during subsequent processing of the raw water for drinking water. Little is known about this process and it has not been examined in samples from the Delta. Decay coefficients for bulk DOC from 10 different habitat types measured in the dark in preliminary experiments ranged from 0.01 to 0.02 day^{-1} and 17-54 % of the DOC originally present was consumed in 16 days. This time scale is similar to the residence time of water in Delta channels and suggests that CALFED managers may need to consider the location and type of restoration projects in relation to drinking water intakes as they plan wetland conversions.

Thus, there is a complex relationship between the extent, location and type of habitat constructed during CALFED restoration efforts, the quality and quantity of dissolved organic carbon released to Delta channels, consumption of dissolved organic carbon in Delta channels by bacteria, and the potential of residual DOC to form DBPs. Another consequence of DOC consumption by bacteria is the generation of food for the Delta foodweb. This relationship is shown schematically in Figure 1, which also presents the questions to be addressed in this study.

Questions/Hypotheses to be evaluated.

1. DOC, including that from agricultural sources, is quantitatively important to the Delta foodweb.
2. DOC composition directly affects its propensity for producing DBP and DOC biodegradibility and utility to Delta foodwebs.

3. A variety of environmental variables, including season, vegetation type, flushing rate/residence time, algal productivity, and others influence the amount and composition of organic material released by wetlands into Delta channel waters.
4. The conversion of existing agricultural lands to wetlands within the Delta will alter the composition of DOC in Delta waters in ways that will affect both the propensity of DOC to form harmful compounds during treatment of the water for use as drinking water, and the biodegradeability of DOC and its quantitative importance as a source of food for the Delta foodweb.
5. DOC from various sources retains chemical characteristics of its origins that may be used to estimate the relative contribution of the sources in Delta waters

Linkages

This project addresses several CALFED ecosystem and water quality goals. In terms of drinking water quality, it addresses water quality concerns at their source (ERPP v. 1, p. 18) and examines potential significant redirected impacts (EIR/EIS Exec. Sum., p. 5) wetland restoration may have on drinking water utilities. It also addresses identified source and load information needs for drinking water parameters of concern (Rev. Wat. Qual. Proj. Plan., p. 15). In terms of Delta foodweb issues, this proposal quantitatively examines producitvity enhancements through wetland restoration (ERPP v. 1, p. 98) and improvements to the Bay-Delta Aquatic Foodweb (ERPP, v. 2, p. 79), and specifically addresses the microbial component of the Delta Foodweb Organisms (ERPP v. 2, p. 83).

This project complements the ongoing CALFED-funded study of POC in the Bay/Delta by USGS scientists and collaborators, and will directly cooperate by sharing samples collected from the sites proposed here. This project also complements the CALFED-funded study of restorations of different ages (Breached Levee Study) by Charles Simenstad and others on the Wetland Ecosystem Team. We will make use of all data already produced by these studies, and all ongoing data collection will be coordinated among the three projects

The agricultural study site identified for this project is the site used in previous USGS/DWR studies on agricultural TOC. DOC characterization results from previous studies also will be used to minimize these costly in-depth analyses and to guide the sampling design. Existing facilities and information for this site will be used for the proposed study and data will be shared wherever possible to minimize costs. We will coordinate sampling methodologies and procedures with another CALFED-funded project (A Learning Laboratory for Restoring Subsided Lands in the Delta, Demonstration of Techniques for Reversing Subsidence in the Sacramento-San Joaquin Delta) scheduled to begin in May 1999.

The agricultural field site is also the site for a study (DOC Production from Cultivated, Organic Soils on Twitchell Island, Sacramento-San Joaquin Delta) being conducted by Professor K.K. Tanji (University of California, Davis) that is funded (1998, 1999) by the Centers for Water and Wildland Resources. The study examines DOC release from peat soils and relates DOC quality to potential formation of THMs. Two of the investigators for this proposed study (Fujii and Bergamaschi) are advisors to the UC Davis study, and study sampling and analysis methodologies will be coordinated to maximize comparability of data. Results from the study will be incorporated in the agricultural operations assessment.

This proposal provides important quantitative information necessary for future models assessing the impacts of specific wetland conversions on Delta water quality at export facilities, and foodweb benefits to the Estuary, once restoration types and locations have been identified.

Compatibility with Non-Ecosystem Objectives

The project provides benefits for the CALFED drinking water quality objectives as well as for the ecosystem health objective. There are no deleterious impacts to other programs

Technical Feasibility and Timing

There are no CEQA, NEPA or other environmental compliance documents required for this proposal. There are no outstanding implementation issues (other than funding).

Monitoring and Data Collection Methodology

Biological/ecological objectives

1. Determine the differences between wetland types and an agricultural field in the concentration and quality of DOC they produce.
2. Assess the quality of DOC produced by different wetland types and an agricultural field with respect to public health concerns that arise when Delta waters are used as drinking water.
3. Determine to what extent microbial processing alters the quality of DOC produced by different wetland types and an agricultural field, thus altering the concentration of the small fraction of DOC causing public health concerns.
4. Determine the differences between wetland types in the bioavailability of the DOC they produce and assimilation into the microbial foodweb.
5. Estimate the amount of wetland- and agriculturally-derived DOC occurring in Delta waters, and thus the potential of DOC from these sources to reach export locations.
6. Analyze and synthesize results, with specific guidelines and recommendations to CALFED about the potential impacts of different restoration actions on drinking water quality and DOC-supported biological production in the Delta.

Monitoring parameters and data collection approach

The study design measures critical representative source and reactive elements affecting DOC composition and DBP precursor concentrations in Delta waters (Fig. 1). The elements to be measured and emphasis of these measurements are indicated by the questions in Figure 1. The approach is to gain a broad understanding of the relationship between DOC sources, release, bioutilization and chemical composition within the Delta system. The key to this study is simultaneous measurement of a wide variety of chemical and biological parameters on a well-chosen set of representative samples collected from throughout the Delta at appropriate hydrologic times. A large number of measured parameters (see Table 2A) are needed to understand the interrelationships between landscape-level features, biological transformations, and parameters of public health concern. Nominations of representative sites (Table 2), sample timing, and analytical methods will be reviewed by a scientific advisory panel (see below) prior to implementation.

Table 2A. Proposed sampling and data collection methods.

I: Determine the differences between wetland types and an agricultural field in the concentration and quality of DOC they produce.		
Hypothesis/Question to be Evaluated	**Monitoring Parameters and Data Collection Approach**	**Data Evaluation Approach and comments**
Do different wetlands types produce different concentrations and quality of DOC?	Collect[1] representative water samples from six different types of wetlands (Sites 3, 5-9 on map). Sample 5 times per year for two years to capture seasonal variability. Samples will be analyzed for TOC and DOC concentrations[2], ultraviolet absorbance (UVA) spectra[3], fluorescence spectra[4], lignin-phenol[5] and carbohydrate[6] contents. DOC will be fractionated and isolated by resin extraction[7], and resulting isolates analyzed for carbon and nitrogen contents and isotopic ratios[8], and ^{13}C-NMR spectra[9].	Statistical comparison of data between wetland types. Integration of data from methods 3-9 to find a "fingerprint" of DOC from each wetland. Incorporate data into geochemical model of the Delta. COMMENT: Coordinate sampling with USGS POC study, and analyses with USGS CA district projects.
Will conversion of agricultural land to wetlands change the concentration and quality of DOC?	Sample water from ditch draining well-studied agricultural field on Twitchell (Site 4). Sample 5 times per year for two years to capture seasonal variability. Samples analyzed by same methods as wetlands samples.	As above, and also integrate data with results from ongoing USGS/DWR study for historical perspective. COMMENT: As above
How does the concentration and quality of DOC in river water change during transit through the Delta to the diversion pumps?	Sample water from Sacramento and San Joaquin rivers upstream from Delta (Sites 1, 2), and from diversion to aqueducts (Site 10). Sample 5 times per year for two years to capture seasonal variability. Samples analyzed by same methods as wetlands samples.	As above
II: Assess the quality of DOC produced by different wetland types and an agricultural field with respect to public health concerns that arise when Delta waters are used as drinking water.		
Hypothesis/Question to be Evaluated	**Monitoring Parameters and Data Collection Approach**	**Data Evaluation Approach and comments**
To what extent does DOC derived from different sources contribute to the formation of DBPs when Delta waters are treated by chlorination?	Use the water samples and isolates already collected and analyzed as part of Objective I (above). Determine chlorine demand[10] and the formation potentials of four chlorination DBP groups: trihalomethane (THM)[11], haloacetic acid (HAA)[12], haloacetonitrile (HAN)[13], and total organic halogen (TOX)[14]	Statistical analysis of results and comparison to historical data.
To what extent does DOC derived from different sources contribute to the formation of DBPs when Delta waters are treated by ozonation?	Use the water samples and isolates already collected and analyzed as part of Objective I (above). Determine ozone demand[15] and the formation potentials of four ozonation DBP groups: carboxylic acids[16], aldehydes[17], aldo-ketoacids[18], and bromate[19].	As above.

Table 2A.Continued. Proposed sampling and data collection methods.

CONTINUED FROM PREVIOUS PAGE ***II: Assess the quality of DOC produced by different wetland types and an agricultural field with respect to public health concerns that arise when Delta waters are used as drinking water.***		
Hypothesis/Question to be Evaluated	**Monitoring Parameters and Data Collection Approach**	**Data Evaluation Approach and comments**
What are the factors affecting DBP formation?	Use the water samples and isolates already collected and analyzed as part of Objective I (above). To supplement the DOC fingerprint already obtained, the samples will also be analyzed for inorganic components bromide[20], and ammonia[21].	Statistical evaluation of relations between DBP formation potentials and DOC quality and inorganic composition.
Can specific organic compounds within DOC be identified as the DBP precursors?	Use a subset of the samples collected and analyzed for Objectives I and II (above). Extract DOC from samples, then separate and analyze stable isotopic ratios in individual compounds by compound-specific GC-IRMS[22]. Analyze products of DBP formation potential experiments (above) by compound-specific GC-IRMS[22].	Compare stable isotopic data for DOC fractions (from Objective I) and individual compounds to data for DBPs to constrain identity of precursor material.
III: Determine to what extent microbial processing alters the quality of DOC produced by different wetland types and an agricultural field, thus altering the concentration of the small fraction of DOC causing public health concerns.		
Hypothesis/Question to be Evaluated	**Monitoring Parameters and Data Collection Approach**	**Data Evaluation Approach and comments**
How does photodegradation affect DBP precursor concentrations?	Use a subset of the samples collected and analyzed for Objectives I and II (above). Seal samples in quartz photolysis bottles and expose to sunlight under controlled experimental conditions. Measure chlorination and ozonation DBP formation potentials (methods 10-19) after experiment.	Statistical comparison of DBP formation potentials of samples before and after experiment.
How does microbial activity affect DBP precursor concentrations?	Use a subset of the samples collected and analyzed for Objectives I and II (above). Seal samples in microcosms innoculated with field-collected bacterial populations under controlled experimental conditions. Measure chlorination and ozonation DBP formation potentials (methods 10-19) after experiment.	Statistical comparison of DBP formation potentials of samples before and after experiment.
Does DOC in exported water represent conservative mixing of river-, wetland-, and agriculture-derived DOC, or have microbial and photolytic activity within the Delta substantially affected the DOC quality?	Analyze samples from photodegradation and microbial degradation experiments for the full suite of DOC characterizations (methods 2-9).	Statistical comparison of DOC quality data in samples before and after experiments to characterize effect of process on DOC composition. Qualitative comparison of DOC quality in export water (Site 10) to calculated mixtures of wetland, agricultural, and riverine DOC, and qualitative comparison of difference to effects observed in processes.

Table 2A. Continued. Proposed sampling and data collection methods.

IV: Determine the differences between wetland types in the bioavailibility of the DOC they produce and assimilation into the microbial foodweb.		
Hypothesis/Question to be Evaluated	**Monitoring Parameters and Data Collection Approach**	**Data Evaluation Approach and comments**
Does DOC from different sources support different microbial communities?	Use the water samples and isolates already collected and analyzed as part of Objective I (above). Measure microbial biomass by determining POC[2] and epifluorescence counting and image analysis[23] of filtrates. Determine phylogenetic composition by PCR/DGGE analysis.	Statistical comparison of data between Sites. Statistical evaluation of relations between microbial community composition and DOC quality parameters (from Objective I)
Do different wetland types, agricultural field, and riverine sources produce DOC with different bioavailibility and nutritional value?	Use the water samples already collected and analyzed as part of Objective I (above). Measure biochemical indicators of biological lability: primary amine and carbohydrate[6] contents. Conduct bioassay experiments with sample water inoculated with field-collected bacteria and incubated under controlled conditions. Determine assimilation efficiencies and decay constants by measuring DOC loss[2], DIC production, O_2 consumption, and biomass production[2,23].	Statistical comparison of data between Sites. Assimilation efficiency and decay constant data also incorporated into model of trophic transfer of DOC.
Does photodegradation increase utilization of DOC by bacteria?	Use a subset of the samples collected and analyzed for Objective I (above). Conduct bioassay experiments in dark and controlled light conditions and measure assimilation efficiencies as above.	Statistical comparison of assimilation efficiencies measured under different experimental conditions.
What is the role of DOC in the bacterial foodweb?	Use the water samples already collected as part of Objective I (above). Isolate bacteria by tangential flow filtration. Isotopic composition[8] of bacteria and bacterial DNA will be separately compared to the isotopic composition[8,22] of the labile elements of the DOC pool.	Statistical comparison of isotopic data from bacteria, bacterial DNA, DOC (from Objective 1), POC (from USGS-POC study).
V. Estimate the amount of wetland- and agriculturally-derived DOC occurring in Delta waters, and thus the potential of DOC from these sources to reach export locations.		
Hypothesis/Question to be Evaluated	**Monitoring Parameters and Data Collection Approach**	**Data Evaluation Approach and comments**
What are the sources of the remnant DOC?	Sources of the remnant material will be estimated using mixing models incorporating both isotopic and compositional parameters ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$[8], carbohydrate[6] and lignin-phenol content[5], ^{13}C-NMR[9]). In select samples, the compound-specific isotopic ratios[22] will be determined. Values will be compared to those obtained by this study in Objective 1, and to the CALFED POC study.	Use multicomponent mixing approach (such as PLS) to decompose residual fractions.
What are the sources of the remnant DOC that degrade drinking water quality?	Measure the isotopic composition of the DBPs directly[22], and compare to the results obtained above.	Statistical comparison of DBP isotopic values to isotopic composition of residual source materials.
What are the sources of foodweb-beneficial DOC in Delta channels?	Use measurements described above in comparison to changes during mesocosm studies to infer labile components in Delta channel samples.	Statistical comparison of important compositional parameters.

Footnotes to Table 2A.

[1]Samples are collected with a flow-through chamber for measurement of in-situ pH, electrical conductivity, temperature, and dissolved oxygen (USGS, 1980). Samples are gravity filtered through 0.45 μm filters on-site and rapidly transported back to USGS labs in amber bottles on ice.

[2]Dissolved organic carbon (DOC) and total organic carbon (TOC) concentrations are measured on filtered and unfiltered samples, respectively, with a Shimadzu TOC 5000A analyzer (Standard Method 5310B). Particulate organic carbon Particulate organic carbon (POC) will be determined by the Cloern study examining this topic.

[3]Ultraviolet absorption spectra are measured from 310 to 190 nanometers wavelength with a Perkin-Elmer Lambda 3B spectrophotometer (Standard Method 5910). Organic structures in the DOC, such as conjugated and aromatic species, absorb UV light at characteristic wavelengths. Thus, the spectra yield information about the type and abundance of organic species within DOC.

[4]Excitation-emission fluorescence spectra are measured with a Spex FluoroMax scanning fluorescence spectrophotometer. Some organic structures in DOC fluoresce (emit light) at characteristic wavelengths when excited by incident light of characteristic wavelengths. The analysis produces a three dimensional map of fluorescence intensity as a function of excitation and emission wavelengths. Deconvolution of the spectra reveals a pattern of fluorphors, which represent a type of "fingerprint" of the DOC in the sample.

[5]Lignin-phenol contents are measured using the cupric oxide oxidation method of Hedges and Ertel (1982). Lignins are integral structural components of terrestrial plants, and are also not easily microbially degraded, thus their abundance indicates relative contribution of terrestrial plants to the DOC and the diagenetic state of the DOC.

[6]Carbohydrate contents are measured using the alditol acetate method of Bergamaschi et al (1997) and Cowie and Hedges (1984). The proportions of individual aldoses in the total carbohydrate are indicative of the source of the carbohydrate (e.g., terrestrial plants, algae, or bacteria) and of the nutritional/energentic value of the carbohydrate to an organism consuming it.

[7]Column fractionation and isolation of DOC are acheived by sequential extraction on nonionic macroporous resins (XAD-8 and XAD-4; Aiken, et al., 1992). The XAD columns separate DOC into operationally defined fractions of hydrophobic, transphilic, and hydrophilic acids. Proportions of fractions provide information about the DOC composition. Lyphilization of the final eluates provides solid isolates of the DOC fractions that can be used for other analytical procedures.

[8]Stable isotopic and elemental compositions of solid materials, including DOC isolates and plant, microbial, and algal biomass, are measured using a Carlo-Erba elemental analyzer interfaced with an Optima stable isotope mass spectrometer (e.g., Bergamaschi et al, in press). Carbon, nitrogen, and sulfur isotopic ratios ($\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$) are extremely useful as tracers of the sources of organic material and of progressive utilization of organic material in the foodweb

[9]Carbon-13 nuclear magnetic resonance spectra (^{13}C NMR) of solid DOC isolates are measured using an NMR spectrometer in cross-polarization magic-angle spinning configuration (Fujii et al., 1998). ^{13}C NMR spectra provide a semi-qualitative measure of the proportions of carbon atoms in different chemical environments within the DOC (aliphatic, heteroaliphatic, anomeric, aromatic, carboxylic, and ketonic carbon).

[10]Chlorine demand refers to the chlorine consumed by reaction with DOC. It is calculated by difference between the chlorine dose applied to the sample and the measured residual chlorine present at the end of the experiment. Free and total chlorine concentrations are measured using the colorimetric DPD method (Hach Methods 8021 and 8167, Standard Method 4500-ClO_2).

[11]Trihalomethane formation potentials (THMFP) are measured following method of Krasner and Sclimenti (1993).

[12]Haloacetic acid formation potentials (HAAFP) are measured following US EPA Method 552.2.

[13]Haloacetonitrile formation potentials (HANFP) are measured following US EPA Method 551.1.

[14]Total organic halide formation potentials (TOXFP) are measured following Standard Method 5320. TOXFP is important to measure because halogenated DBPs other than THM, HAA, and HAN may be formed.

[15]Ozone demand refers to the ozone consumed by reaction with DOC. It is calculated by difference between the ozone dose applied to the samples and the measured residual ozone present at the end of the experiment using Standard Method 4500-O_3.

[16]Carboxylic acid formation potentials are measured following the method of Kuo, et al. (1996).

[17]Aldehyde formation potentials are measured following Standard Method 6252.

[18]Aldo-ketoacid formation potentials are measured following the method of Hwang, et al. (1996).

[19]Bromate concentrations are meadured following US EPA Method 300.1.

[20]Bromide concentrations are measured by ion chromatography following Standard Method 4500-Br^-.

[21]Total ammonia concentrations as nitrogen are measured using the salicylate colorometric method (Hach Method 8155).

[22]Compound-specific gas chromatography-isotope ratio mass spectrometry (GC-IRMS) is performed using a Hewlett-Packard 5890 II gas chromatograph analyzer interfaced with an Optima stable isotope mass spectrometer following the methods of Bergamaschi et al (in press) and Merritt et al. (1995). DOC is composed of numerous molecular structures, each with different source, chemical and isotopic composition, and reactivity to form particular DBPs. Comparison of the isotopic composition of DBPs with individual compound in the DOC provides conclusive information about exactly which compounds are the precursors.

[23]Epifluorescence counting, following Standard Method 9216, is used to directly determine the total number of bacterial cells in the sample. Further image analysis permits assessment of bacterial morphologies.

Data evaluation approach

A Scientific Advisory Panel will review the work plan and interpretative reports generated by the study to ensure the highest standards of scientific quality and integrity. Scientists representing a wide range of expertise have agreed to serve in this advisory capacity:

Prof. Gary Amy (U. Co.), an internationally recognized expert on DBP formation in drinking water treatment. Dr. Amy recently served on the CALFED Bromide expert panel.

Dr. George Aiken (USGS Boulder), with more than 20 years experience analyzing DOC from throughout the world using ^{13}C-CPMAS NMR.

Dr. Ronald Benner (U. Texas), who provides expertise on compositional characteristics of DOC released from wetlands and the utilization of DOC by microbial communities.

Dr. Bryan Fry (U. La.), an expert at application of isotopic techniques to foodweb studies.

Dr. James Cloern (USGS Menlo Park), internationally recognized for contributions on foodweb carbon dynamics. Dr. Cloern also provides an important interpretive link to the existing CALFED-funded study on POC.

Dr. Charles Simenstad (U. Washington), Director of the Wetlands Ecosystems Team, is currently engaged in a CALFED funded study on wetlands formed following levy breaches, and provides expertise on wetland habitats.

Douglas M. Owen, P.E. (Malcolm-Pirnie, Inc.), an expert consultant on the role of natural organic matter in the formation of DBP, and removal in the water treatment process. Dr. S. Geoffrey Schlader (UC Davis) is an expert on constituent transport in estuarine and reverine environments.

Dr. K.K. Tanji (U. C. Davis) is an internationally recognized expert on irrigated agricultural systems and has had extensive experience working with peat soils in the Delta.

Local involvement

All counties in the Delta region have been notified that we are submitting this proposal (see attached letters). As an indication of the broad level of support for this project, the following groups have indicated they have sent letters of support directly to CALFED offices.

Delta Protection Commission

Natural Heritage Institute

Save the Bay

NRDC

Bay Institute

Contra Costa Water District

Santa Clara Water District

Three Valleys Municipal Water District

Metropolitan Water District

California Urban Water Agencies

Cost

Budget

Table 3. Total Budget (CALFED funds only)

Task	Direct Labor Hours	Direct Salary and Benefits	Service contracts	Material and Acquisition Costs	Miscellaneous Direct Costs (travel, tuition, publication costs)	Overhead and Indirect Costs	**Total Cost**
1 Sources	6302	201214	61200	20121	4024	168427	**454987**
2. Foodweb value	10460	169302	0	3000	85787	95491	**364040**
3.Changes in DOC	2894	97877	19800	9788	1958	88575	**217997**
4. Channel DOC	2200	92072	0	42000	7500	49267	**190839**
5. Synthesis Report	740	19405	0	0	388	25658	**46191**
6. Science Advisory Panel			34500			1656	**36156**
7. Project Management	1048	32755				49704	**82459**
TOTAL by category	23644	612625	115500	74909	99657	478777	**1392669**

Overhead and other Indirect Costs for the USGS: Indirect costs of the U.S. Geological Survey (USGS) are a combination of National (WOTSC) and District (DOTSC) costs. Each percentage rate is determined at its appropriate level - simplistically, the WOTSC percentage is based on Headquarters and Regional Office expenditures divided by the entire anticipated USGS funding, the DOTSC percentage is based on each District's common services expenditures divided by the District's anticipated funding. These percentages are then applied separately to the net expenses of a proposal.

WOTSC consists of labor and non-labor expenses for Headquarters and Regional Office staffs, along with general expenses such as (but not limited to) rent, communications and database management. DOTSC consists of labor and non-labor expenses at the District level for Management and Services Support staffs (technical, administrative, computer, database management and general reports), and general District expenses such as (but not limited to) rent, communications and database management.

Justification for other entities are attached.

Quarterly Budgets

Table 4. Quarterly Budgets (CALFED funds only)

TASK	Oct-Dec 99	Jan-Mar 00	Apr-Jun 00	Jul-Sep 00	Oct-Dec 00	Jan-Mar 01	Apr-Jun 01	Jul-Sep 01	Oct-Dec 01	Jan-Mar 02	Apr-Jun 02	Jul-Sep 02	Total Budget
1	45499	45499	45499	45499	45499	45499	45499	45499	22749	22749	22749	22749	454987
2	36404	36404	36404	36404	36404	36404	36404	36404	18202	18202	18202	18202	364040
3	21800	21800	21800	21800	21800	21800	21800	21800	10900	10900	10900	10900	217997
4	19084	19084	19084	19084	19084	19084	19084	19084	9542	9542	9542	9542	190839
5	1443	1443	1443	1443	1443	1443	1443	1443	8661	8661	8661	8661	46191
6	3616	3616	3616	3616	3616	3616	3616	3616	1808	1808	1808	1808	36156
7	8246	8246	8246	8246	8246	8246	8246	8246	4123	4123	4123	4123	82459
Total	136091	136091	136091	136091	136091	136091	136091	136091	75985	75985	75985	75985	1392669

Schedule

Each task will submit annual reports and a final summary interpretive report. Summary reports will be completed 36 months after start of project. Progress reports will mainly document data results. In coordination with similar studies, we will convene annual conferences for CALFED and other interested parties and stakeholders at which results and progress will be presented and extended abstracts published. It is anticipated that some results also will be published as USGS reports and in peer-reviewed journals.

Table 5. Project schedule.

TASK	Oct-Dec 99	Jan-Mar 00	Apr-Jun 00	Jul-Sep 00	Oct-Dec 00	Jan-Mar 01	Apr-Jun 01	Jul-Sep 01	Oct-Dec 01	Jan-Mar 02	Apr-Jun 02	Jul-Sep 02
1 SOURCES												
Field sampling and experimental	X	X	X	X	X	X	X					
Analysis		X	X	X	X	X	X	X	X	X		
Quarterly Report	X	X	X	X	X	X	X	X	X	X		
Annual Data Report and presentation				X				X				
Final Report and presentation											X	X
2. FOODWEB VALUE												
Field sampling and experimental	X	X	X	X	X	X	X	X				
Analysis	X	X	X	X	X	X	X	X				
Quarterly Report	X	X	X	X	X	X	X	X	X	X	X	
Annual Data Report and presentation				X				X				
Final Report and presentation											X	X
3.CHANGES IN DOC												
Field sampling and experimental	X	X	X	X	X	X	X					
Analysis		X	X	X	X	X	X	X	X			
Quarterly Report	X	X	X	X	X	X	X	X	X	X		
Annual Data Report and presentation				X				X				
Final Report and presentation											X	X
4. CHANNEL DOC												
Field sampling and experimental												
Analysis												
Quarterly Report												
Annual Data Report and presentation												
Final Report and presentation												
5. SYNTHESIS REPORT												
Assemble data				X				X			X	
Final report											X	X
6. SCIENCE ADVISORY PANEL												
Review workplan	X											
Review progress				X			X			X		
Review interpretive report										X	X	X

Products and potential for incremental funding

Tasks 1-4 will produce annual and final scientific reports. Task 5 will synthesize elements of tasks 1-4 into specific recommendations to CALFED. Task leaders will bear responsibility for report preparation. Tasks 1, 2 and 3 represent the core of this project and can not be separated. Separate knowledge of the source, chemical composition, and degradability of DOC is required to predict the effects of contemplated land-use changes. The fourth task could be separated for funding at a later time, but it would cost much more as the field component is highly integrated into tasks 1-3. Identifying the wetland sources of carbon entering the foodweb or at the drinking water intake will directly establish the relationship between sources and the points of interest. Task five, the synthesis of results, can not be separated. The scientific advisory panel, task six, can be separated or reduced, but we think that the scientific credibility provided by a panel of expert peers to review project products is important. The questions addressed here are very complex and elimination or reduction of the panel may affect the high quality of the final product.

Cost Sharing

This study will be integrated within the ongoing Category III study of particulate organic carbon, a jointly-funded three-year project between USGS ($0.8M) and CALFED ($1.4M). This CALFED CATEGORY III POC proposal to Jim Cloern forms the basic logistical element of this study. Logistical savings (field sampling, boat time, etc.) are estimated to be $150000. Salary support ($72540) for Carol Kendall's participation in the proposed study will be provided by the USGS. Similarly, the USGS will support George Aiken and Jim Cloern to participate in the scientific advisory panel. ($10240). The University of Georgia will supply funding for Tim Hollobaugh ($47800) and Mary Ann Moran. ($23100).

Applicant Qualifications

Brian Bergamaschi received a Ph.D. in Chemical Oceanography from the University of Washington, in Seattle, WA, where he specialized in analyzing the sources and fates of natural organic material in the environment. For that work, he received an award for an outstanding dissertation in Chemical Oceanography (ONR/NSF). He was also the recipient of the Barbara McClintock postdoctoral fellowship at the Carnegie Geophysical Laboratory. For the past 4 years, he has been working with the USGS on matters relating to the activity of natural organic material in the environment, and especially in the Sacramento-San Joaquin Delta. Recently, he has been focusing on the sources of DBP precursors in surface waters. Recent relevant publications include:

Bergamaschi, B.A., Fram, M.S., Kendall, C., Silva, S.R., Aiken, G.R., and Fujii, R (1999) Carbon isotopic constraints on the contribution of plant material to the natural precursors of trihalomethanes. In press. Organic Geochemistry.

Bergamaschi B. A., Baston D. S., Crepeau K. L., and Kuivila K. M. (1999) Determination of pesticides associated with suspended sediments in the San Joaquin River, California, U.S. A., using gas chromatography-ion trap mass spectrometry. In Press. Toxicological and Environmental Chemistry.

Bergamaschi B. A., Walters J. S., and Hedges J. I. (1999) Distributions of uronic acids and *O*-methyl sugars in sinking and sedimentary particles in two coastal marine environments. In Press. Geochimica et Cosmochimica Acta.

James T. Hollibaugh (BS University of California-Davis, 1971; Ph.D. Dalhousie University, 1977) is Professor and Associate Director of the School of Marine Programs, University of Georgia. Previous position was Senior Research Scientist and Acting Director, Romberg-Tiburon Center for Environmental Studies. Dr. Hollibaugh has 25 years experience in studies of dissolved organic matter-microbe interactions, and he has worked extensively in San Francisco Bay and the Delta. He has served as Associate Editors for the journals *Limnology and Oceanography, Aquatic Microbial Ecology*, and *Estuaries*. Three recent publications:

Werner, I. and J.T. Hollibaugh. 1993. Potamocorbula amurensis (Mollusca, Pelecypoda): Comparison of clearance rates and assimilation efficiencies for phytoplankton and bacterioplankton. Limnology and Oceanography 38: 949-964.

Hollibaugh, J.T. and P.S. Wong. 1996. Distribution and activity of bacterioplankton in the San Francisco Bay estuary. In: J.T. Hollibaugh, [Ed.]; San Francisco Bay: The Ecosystem. Pacific Division, AAAS, San Francisco, California. pp. 263-288.

Hollibaugh, J.T. and P.S. Wong. 1999. Microbial processes in the San Francisco Bay estuarine turbidity maximum. Estuaries, in press.

Miranda Fram received her Ph.D. in Geological Sciences from Columbia University and the Lamont-Doherty Earth Observatory in New York, and was then awarded a University of California President's Postdoctoral Fellowship at UC Davis. For the last 1 ½ years she has been with the USGS working on a variety of projects concerning organic carbon composition and DBP formation, primarily in Delta waters, and developing methods for analyzing trihalomethane formation potentials, and the carbon isotopic composition of trihalomethanes. Recent publications include:

Fram, M.S., Bergamaschi, B.A., Kendall, C., Silva, S.R., Aiken, G.R., and Fujii, R (1998) Changes in the carbon isotopic composition of trihalomethane formed during progressinve chlorination of dissolved humic material. Amer. Chem. Soc., Div. Environ. Chem., Preprints E: Absts., v. 38, p. 52-53.

Fram, M.S. and Lesher, C.E. (1997) Generation and polybaric differentiation of East Greenland Early Tertiary flood basalts. Journal of Petrology, 38, p. 231-275.

Richard F. Losee (Ph.D., Botanical Limnology, Michigan State University, 1991) is Senior Limnologist, Metropolitan Water District Of Southern California. Since 1993 he has managed 7 of southern California's drinking water reservoirs for water quality. He has provided expert testimony to the State Water Resources Control Board on Delta wetland and reservoir organic carbon production; participated in the design of reservoir and reservoir inlet and outlet facilities to maximize operational flexibility, and optimization of taste and odor control to minimize dependence on the use of algaecides.

Losee, R.F., W.D. Taylor, R.L. Wolfe, and B. Koch. 1994. Analysis of historical taste-and-odor data for operational and engineering design decisions. Proceedings of the 1994 American Water Works Association, Water Quality Technical Conference, San Francisco, California.

Taylor, W.D., R.F. Losee, G. Izaguirre, D.J. Crocker, D.J. Otsuka, R.D. Whitney, J. Kemp and G. Faulconer. 1994. Application of Limnological principles for management of taste and odor in drinking water reservoirs: a case study. Proceedings of the 1994 American Water Works Association, Water Quality Technical Conference, San Francisco, California.

Stuart W. Krasner (BS Chemistry, MS Analytical Chemistry, UCLA). With 21 years at Metropolitan Water District investigating the formation and control of disinfection by-products (DBPs)—particularly those associated with chlorination, chloramination, ozonation, and bromide-containing waters. He was a member of the AWWA Technology Workgroup in Support of the regulatory negotiations for the D-DBP Rule has provided expert testimony to the State Water Resources Control Board on Delta wetland and reservoir organic carbon potential to form disinfectant byproducts.

Krasner, S. W., M. J. Sclimenti, and E. G. Means. 1994. Quality Degradation: implications for DBP formation. Journal of the American Water Works Association, 86(34-47).

Roger Fujii received his Ph.D. in soil chemistry from the University of Wisconsin, Madison, in 1983. Dr. Fujii has conducted applied geochemical research for the USGS since 1984 and is currently the Project Chief for the USGS Drinking Water Initiative study of the Sacramento-San Joaquin River Delta, which focuses on drinking water quality issues related to DOC and DBPs. Dr. Fujii is senior author of a recently published report entitled "Dissolved Organic Carbon Concentrations and Composition, and Trihalomethane Formation Potentials in Waters from Agricultural Peat Soils, Sacramento-San Joaquin Delta, California: Implications for Drinking-Water Quality" (USGS Water Resources Investigations Report 98-4147).

Mary Ann Moran (B.S. Colgate University, 1977; M.S., Cornell University, 1982; Ph.D. University of Georgia, 1987) is Associate Professor in the Department of Marine Sciences at the University of Georgia. Dr. Moran has conducted research on dissolved organic matter for 15 years, and has expertise in the microbiology, photochemistry, and ecology of organic matter turnover in estuaries, marshes, and coastal waters. She is currently serving as an Associate Editor for the journal *Limnology and Oceanography*, and as a member of the editorial board for *Applied and Environmental Microbiology*. Moran's recent relevant publications include:

Moran, M. A., and R. E. Hodson. 1994. Dissolved humic substances of vascular plant origin in a coastal marine environment. *Limnology and Oceanography* 39:762-771.

Moran, M. A. and R. G. Zepp. 1997. Role of photoreactions in the formation of biologically labile compounds from dissolved organic matter. *Limnology and Oceanography* 42:1307-1316.

Miller, W. L., and M. A. Moran. 1997. Interaction of photochemical and microbial processes in the degradation of refractory dissolved organic matte from a coastal marine environment. *Limnology and Oceanography* 42:1317-1324.

Moran, M. A., W. M. Sheldon, and J. E. Sheldon. 1999. Biodegradation of riverine dissolved organic carbon in five estuaries of the Southeastern United States. *Estuaries*. In press.

Carol Kendall received her Ph.D. in Geochemistry from the University of Maryland, where she specialized in aqueous geochemistry. Dr. Kendall is Project Chief for the USGS Isotope Tracers Project, which focuses on isotopic techniques for tracing sources of water and solutes in shallow hydrologic regimes. A recent research emphasis has been tracing tracing sources of nutrients and trophic relations in the Everglades. She was vice-chair of the 1993 Gordon Conference on Hydrologic, Geochemical, and Biological Processes in Forested Catchments; regularly teaches Isotope Hydrology courses for the USGS and the GSA; was chair of the AGU Water Quality Committee 1995-97; and is co-editor of a recently published textbook: Kendall, C. and McDonnell, J.J. (Eds.), 1998, "Isotope Tracers in Catchment Hydrology", Elsevier, 839 p. Other relevant publications include:

Kendall, C., 1998, Sources and cycling of nitrate, In: C. Kendall and J.J. McDonnell (Eds.), Isotope Tracers in Catchment Hydrology, Elsevier, Amsterdam, p. 519-576.

Hunt, R.J., Bullen, T.D., Krabbenhoft, D.P., and Kendall, C., 1998, Using stable isotopes of water and strontium to investigate the hydrology of a natural and a constructed wetland, Ground Water, v. 36, p. 434-443.

Robert Dias is a Ph.D. candidate in Geological Sciences at Penn State University (expected completion, June 1999). For the past six months he has been with the USGS working on a variety of projects including the application of compound-specific isotope analysis to foodweb studies, petroleum contamination in environmentally sensitive areas and stable isotope instrument and method development. Recent publications include:

Dias R.F. and Freeman K.H. (1997) Carbon-isotope analysis of semivolatile organic compounds in aqueous media using solid-phase microextracti and isotope ratio monitoring GC/MS. Analytical Chemistry 69(5):944-950.

I-019324

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Water Resources Division
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Sacramento, California 95819-6129
(916) 278-3053 Fax (916) 278-3071 bbergama@usgs.gov

Memorandum

Date: March 30, 1999

Subject: **Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 1. Compositional Characteristics.**

Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: Bay Conservation and Development Commission

30 Van Ness Avenue, Room 2011

San Francisco, CA 94102

Dear Sir or Madam:

This memo is to inform you that we will be submitting the two proposals identified in the subject line above in response to the CALFED Bay-Delta Program February 1999 Proposal Solicitation. CALFED requires that we provide notification to counties that may be affected by proposed work prior to submission.
Rivers, wetlands, and agricultural operations supply organic material to the Sacramento-San Joaquin Delta and San Francisco Estuary, providing essential nutritive material to the food web and thus an important ecosystem benefit. Unfortunately, organic material in Delta drinking source waters increases the difficulty of treating those waters, and may result in the formation of carcinogenic disinfection byproducts (DBPs) regulated by US EPA.

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Memorandum

Date: March 30, 1999

Subject: Dissolved organic carbon release from Delta wetlands: amounts, alterat[...] and implications for drinking water quality and the Delta foodweb, part Compositional Characteristics.

Dissolved organic carbon release from Delta wetlands: amounts, alterati[...] and implications for drinking water quality and the Delta foodweb, part Fluxes and Loads

To: Delta Protection Commission

14215 River Road

P.O. Box 530

Walnut Grove, CA 95690

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Memorandum

Date: April 14, 1999

Subject: Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 1. Compositional Characteristics.

Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: Community Development Planning Supervisor

1810 E. Hazelton Avenue

Stockton, California

Dear Sir or Madam:

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Dissolved organic carbon release from Delta wetlands: amounts, alteratio[...] and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: County Board of Supervisors

222 E. Weber Avenue, Room 701

Stockton, California

Dear Sir or Madam:

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Memorandum

Date: March 30, 1999

Subject: **Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 1. Compositional Characteristics.**

Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: Yolo County Planning Supervisor
292 W. Beamer Street
Woodland, CA

Dear Sir or Madam:

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Date: March 30, 1999

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Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: Yolo County Supervisor
625 Court Street
Woodland, CA

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Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: Contra Costa County Supervisor
651 Pine Street, Room 108A
Martinez, CA 94553

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Date: March 30, 1999

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Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: Contra Costa Planning Supervisor
651 Pine Street, No. Wing, Fourth Floor
Martinez, CA 94553

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Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: Sacramento County Planning Supervisor
700 H Street
Sacramento, CA 95814

Dear Sir or Madam:

This memo is to inform you that we will be submitting the two proposals identified in the subject line above in response to the CALFED Bay-Delta Program February 1999 Proposal Solicitation. CALFED requires that we provide notification to counties that may be affected by proposed work prior to submission.
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Dissolved organic carbon release from Delta wetlands: amounts, alterations, and implications for drinking water quality and the Delta foodweb, part 2. Fluxes and Loads

To: Sacramento County Supervisor
700 H Street
Sacramento, CA 95814

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To: Solano County Supervisor
580 Texas Street
Fairfield, CA 94533

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TE OF CALIFORNIA

NONDISCRIMINATION COMPLIANCE STATEMENT

STD. 19 (REV. 3-95) FMC

COMPANY NAME

The Metropolitan Water District of Southern California

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unl specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and development, implementation and maintenance of a Nondiscrimination Program. Prospective contrac agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant employment because of sex, race, color, ancestry, religious creed, national origin, disability (includi HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care lea and denial of pregnancy disability leave.

CERTIFICATION

I, the official named below, hereby swear that I am duly authorized to legally bind the prospecti contractor to the above described certification. I am fully aware that this certification, executed on t date and in the county below, is made under penalty of perjury under the laws of the State of Californ

JEANNE-MARIE BRUNO

OFFICIAL'S NAME

4/14/99

DATE EXECUTED

EXECUTED IN THE COUNTY OF

LOS ANGELES

Jeanne-Marie Bruno

PROSPECTIVE CONTRACTOR'S SIGNATURE

ACTING ASSOCIATE DIRECTOR OF WATER QUALITY

PROSPECTIVE CONTRACTOR'S TITLE

METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME

DISSOLVED ORGANIC CARBON RELEASE FROM DELTA WETLANDS: AMOUNTS, ALTERATIONS, AND IMPLICATIONS FOR DRINKING WATER QUALITY AND THE DELTA FOODWEB. PART 1. COMPOSITIONAL CHARACTERISTICS.

Primary Contact:

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U.S. Geological Survey
California State University, MS 6129
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Phone: (916) 278-3053; Fax: (916) 278-3071
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Participants and Collaborators

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